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**CREW EMERGENCY RETURN VEHICLE
(CERV) AVIONICS**

**SPACE TRANSPORTATION AVIONICS
TECHNOLOGY SYMPOSIUM**

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**ASSURED CREW RETURN CAPABILITY
CREW EMERGENCY RETURN VEHICLE (CERV) AVIONICS**

WHITE PAPER

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Background

NASA is currently investigating a Crew Emergency Return Vehicle (CERV) to provide assured crew return for Space Station Freedom. While the Space Station, in conjunction with the Space Shuttle, is capable of handling many emergency situations on its own, NASA has found at least three situations where a CERV is essential:

- O Medical Emergency - Provide the crew with the ability to evacuate seriously injured/ill crewmember from the Space Station to a ground based care facility under medically tolerable conditions.
- O Station Catastrophe - Provide the crew with the ability for a safe and time-critical evacuation of the Space Station in the event the Space Station becomes uninhabitable.
- O Shuttle Problems - Provide the crew with the ability to return safely to Earth from the Space Station in the event NSTS flights are interrupted for a time that exceeds Space Station ability for crew support and/or safe operations.

The NASA Phase A investigations over the past several years identified the above requirements and they have been documented as Design Reference Missions 1, 2, and 3 respectively (DRM's 1, 2, 3) within the CERV Systems Performance Requirements Document (SPRD), JSC 31017.

The CERV SPRD has been prepared as functional and performance requirements in such a manner as to minimize design specificity of the requirements. The CERV Project intent is to identify the minimum set of requirements that will enable the project objective of a simple, reliable, cost effective vehicle and give the contractor maximum design freedom. The CERV Phase A'/B procurement effort, currently scheduled to begin October 2, 1989, is intended to affirm the existing project requirements or to

amend and modify them based on thorough evaluation of the contractor(s) recommendations.

The CERV design must be capable of simple, nearly automatic operation because its control will probably be by a physically deconditioned crew. Therefore, although crew intervention may be required, it is not envisioned that CERV operation will require highly trained piloting skills to operate the CERV for separation, deorbit, entry, and landing activities.

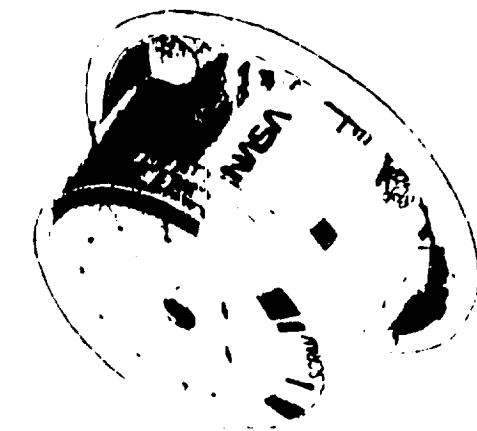
The CERV must be available for immediate use throughout the life of the Space Station. Therefore, reliability is an important design requirement for the CERV. If the CERV is to be a highly reliable vehicle, the onboard systems must be simple, and use proven state-of-the-art technology, with robust design margins and sufficient systems redundancy to be available for immediate use.

Long periods of dormancy are a desirable design objective. Dormant systems exhibit higher reliability than those that are active. However, establishing confidence in the CERV System may require periodic systems health check tests and evaluations. These periodic system health checks would be made utilizing the CERV avionics hardware/software systems in conjunction with the Space Station and must be capable of diagnostic isolation of a failed system to the ORU level. This implies, among other things the of sharing some limited resources with the Space Station, e.g. power, ECLSS, communications, personnel, etc..

To enhance CERV System reliability while minimizing life cycle costs, it will be a Program goal to embed CERV operations within existing, ongoing programs such as NSTS and Space Station Freedom. Launch and delivery of the CERV to Space Station Freedom will be accomplished using existing NSTS and ELV capabilities. Once at the Space Station, CERV activation, periodic checkout, and maintenance will become an integrated part of the Space Station workday activity, although with minimal interference to ongoing productive activities. On the ground, existing facilities and personnel at KSC will largely suffice for prelaunch processing, logistics, and turnaround operations. The highly flexible workstations and reconfiguration environment currently under development at JSC for the NSTS and Space Station Control Centers will enable those facilities to accommodate CERV mission planning and real-time support. And finally, a vital link in the operations concept will be provided by reliance upon existing worldwide Search and Rescue capabilities, both U.S. and international.

The JSC CERV Project Office, during its in-house Phase A studies, evaluated the following four CERV concepts (shown in figure 1): a) The Reference Configuration, b) The Benchmark Configuration - SCRAM, c) The Apollo Derivative, and d) The LaRC Lifting Body Configuration.

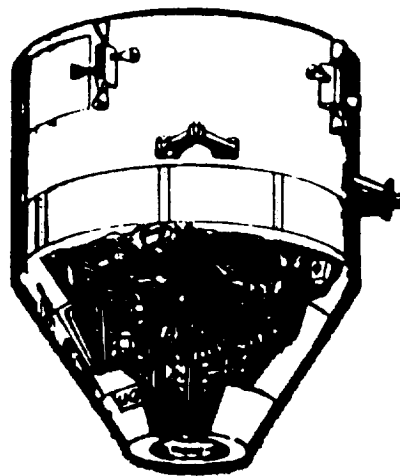
Candidate CERV Vehicle Approaches



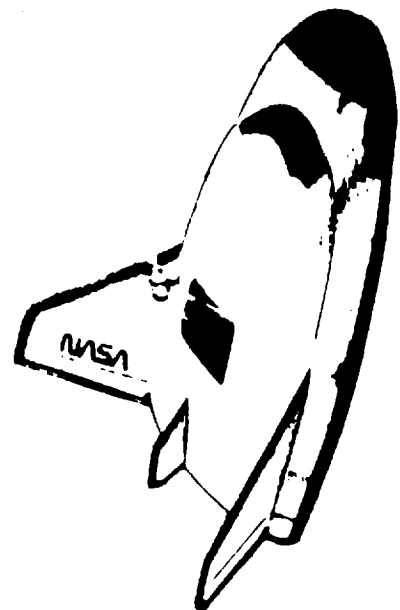
SCRAM VEHICLE



DISCOVERER SHAPED VEHICLE



APOLLO DERIVED VEHICLE



MID - L/D VEHICLE

FIGURE 1. CERV PHASE A STUDY CONFIGURATIONS

The following treatment of the CERV avionics systems is presented with the caveat that a firm CERV system design has not been selected at this time. The following discussion is not to be construed as expressing a preferential avionics system/subsystem configuration by the JSC CERV Project Office.

For the purposes of this symposium the reference configuration concept avionics systems will be presented.

CERV Avionic Systems

The avionics systems design is required to perform the three DRM's with minimal crew participation. It is assumed that the crew will have limited training in CERV operations, as well as being in a physically deconditioned state. The crew may participate in some simple operational functions; however, those functions that require skilled piloting capabilities will be automated.

Another avionics systems design goal is availability. Availability dictates a fail-safe avionics system/subsystem that will be backed up by redundancy in critical systems, by other systems/subsystems automatically, or by limited crew participation.

Space Station emergencies, DRM2, place the most severe requirements on the avionics system/subsystem. The CERV must be in a safe configuration and ready for departure within minutes after a Space Station emergency is declared and it is determined that crew evacuation is required. This condition will allow minimal planning, warmup, and checkout time.

The avionics hardware design objectives will be to comply with the Space Station interfaces and possess some degree of ORU commonality. The ORU commonality is desirable from the CERV standpoint to the extent that simplicity and reliability is not compromised.

The JSC CERV Project Office Phase A reference configuration concept evaluations identified the following systems:

- Guidance, Navigation, and Control
- Displays and Control
- Communication and Tracking
- Electrical Power
- Propulsion
- Pyrotechnic
- Environmental Control and Life Support
- Thermal Protection
- Medical
- Landing and Recovery

Of these systems the first four are considered to make up the avionics systems. The remainder are integrally related to the avionics in the demand-command response sense.

The system contains dual avionics strings for redundancy. Two General Purpose Computers (GPC's) with their associated software and Multiplexer/De-Multiplexers (MDM's) comprise the heart of the system, essentially the Data Management System (DMS). The GPC's will run simultaneously but not synchronously. The primary GPC will be in control of system operation until a fault is detected; then it will be automatically switched to the secondary GPC. Individual ORU's will be selected or deselected automatically by the GPC's. Fault detection logic to select other systems/subsystems will also be contained in the GPC's to operate similarly to the above fault selection subsystem. Manual override will be possible through keyboard entries. Dual MDM's will be used to interface the other GN&C subsystems and Reaction Control System (RCS) jet drivers to the GPC's. The dual Inertial Measurement Units (IMU's), dual Horizon Sensors and Global Positioning System (GPS) will also be interfaced to the GPC's through the MDM's. Sensor data, including medical, will be linked through the MDM to the GPC for onboard decision-making or for downlink to the ground by the S-band.

A single-string GPS system could be used to obtain the state vector for CERV, especially in the DRM-2 application. Where time permits prior to Space Station separation, the CERV state vector initialization will be obtained by an exchange of information with the Space Station. The backup for acquiring a state vector will be the single-string S-band with telemetry and command uplink capability. A state vector can also be entered manually via the keyboard.

Guidance, Navigation, and Control (GN&C)

The GN&C system block diagram is shown in figure 2. The system possesses the following characteristics:

- 0 Two strings with cross-strapping between units
- 0 Strings consist of:
 - General Purpose Computers
 - Multiplexers/De-Multiplexers
 - Inertial Measurement Units
 - Horizon Scanner
 - Reaction Jet Drivers (RJD's)
- 0 Horizon sensors and gyrocompassing are used for attitude alignment
- 0 Sensors provide systems information to the GPC's for systems control and/or for use with communications or telemetry
- 0 The GPC's provide control to most of the CERV systems/subsystems

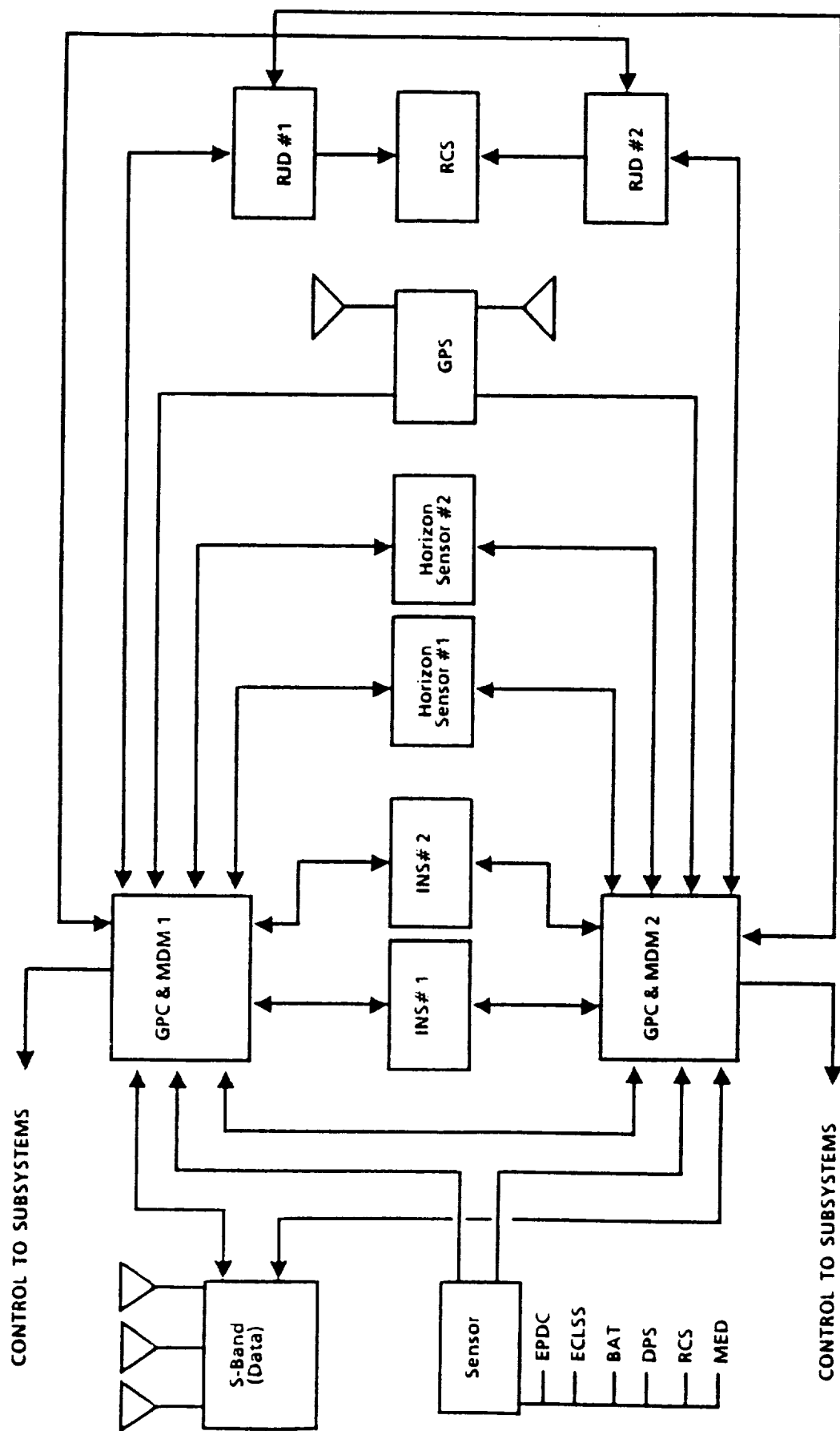


FIGURE 2. GN&C SYSTEM

CERV Software

The CERV software will be developed independently of the Space Station software; however, in keeping with aforementioned embedded operations, its development may use the existing Space Station Program rules and tools, e.g. Software Support Environment (SSE). Space Station software interface criteria will be satisfied such that periodic health test checkout and evaluations can be performed. The software subsystem will control the sequence of the startup and shutdown of CERV systems/subsystems and will provide GN&C for Space Station separation, landing site targeting, deorbit maneuvers, reentry control, and landing.

Since this software is designed for an emergency vehicle, there should be no constraint on its use in unexpected situations. The software will also support the fault detection and isolation functions. For durability, reliability, and quick activation, the software may be put into the read only memory (ROM) of the GPC's. Provisions for updating the CERV software will be included. For example, the CERV is currently thought to interface to the Space Station resource nodes one and three, top ports. Should the Space Station configuration change such as to impact the CERV location and departure trajectory, then the CERV GN&C will have to change.

Displays and Controls

The Displays and Controls (D&C) subsystem is designed to minimize the crew interface but to allow some manual override if necessary. Manual override will not be required but will support system reconfiguration if such is required. Manual control will be allowed for noncritical systems based on cost, training factors, and subsystem complexity. In keeping with the philosophy of minimizing crew interface and training, no hand controls are provided for vehicle maneuvering.

The primary interface between the crew and CERV subsystems may be electroluminescent (EL) screens and keyboards. These units will be used to monitor subsystems, display information, and provide inputs to the GPC's. Reconfiguration of the avionics and communications subsystems can be accomplished manually if so desired. The crew will also have access to switches and circuit breakers for manual override in limited circumstances. A caution and warning display and master alarm will be provided to enhance safety. A fire detection and suppression system will also be provided.

Manual control will be provided for a portion of the ECLSS related to crew comfort and for lighting. The UHF communications subsystem will be manually controlled by the crew. The Search and Rescue Satellite (SARSAT) system will be controlled by the GPC's.

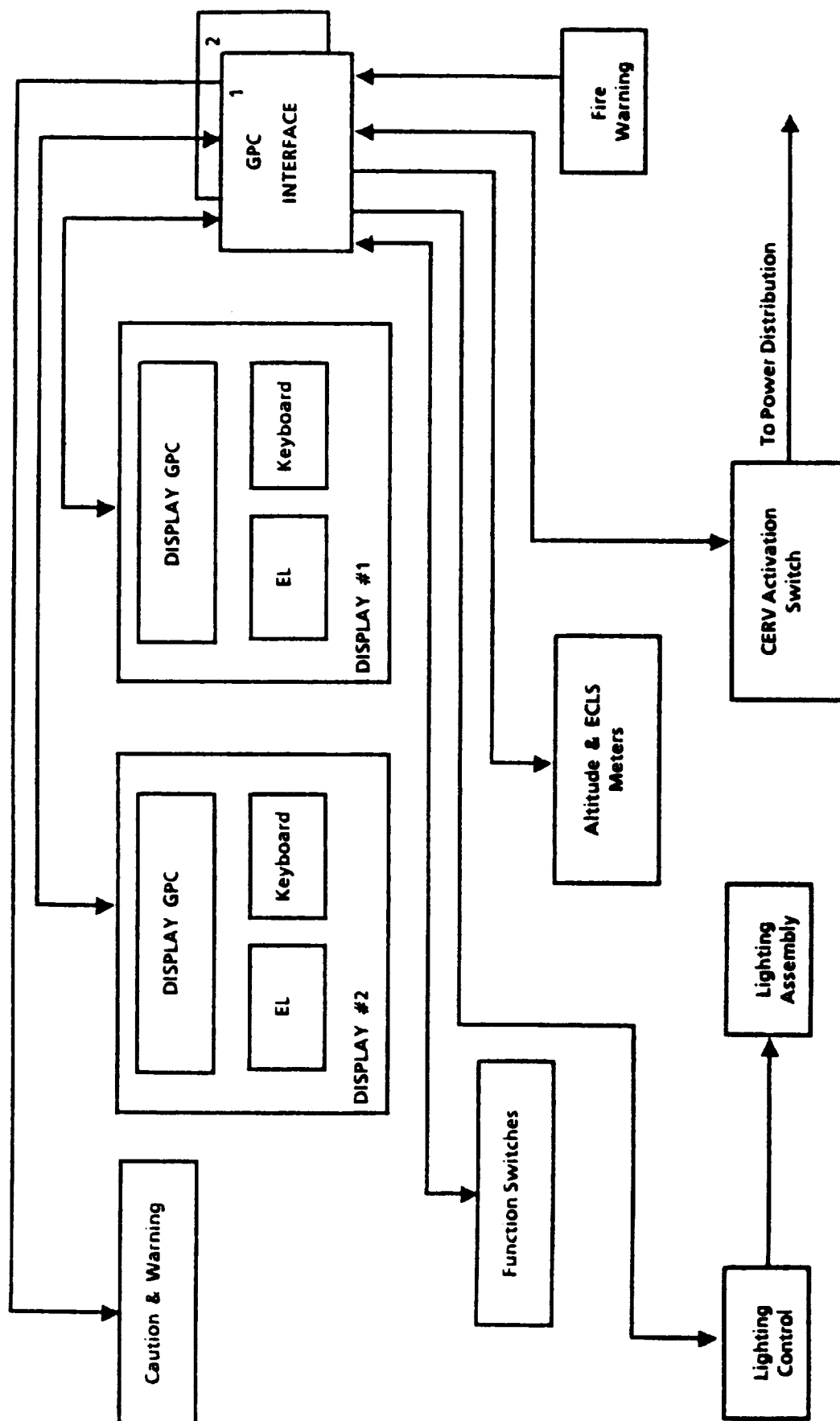


FIGURE 3. DISPLAYS AND CONTROLS SYSTEMS

The D&C system is completely redundant and is derived from the Space Station work station. It contains an embedded processor to relieve the GPC of the task of formatting and displaying data. The similarity to the Space Station work station will minimize CERV training. Figure 3 is an example of such a display and control subsystem.

Communications and Tracking

The communications subsystem will be a single-string subsystem with the redundancy provided by other backup subsystems. The communication subsystem will be automatically controlled by the CERV GPC with manual override by the crew being provided through the D&C keyboard. The UHF subsystem, except for the SARSAT beacon, will be manually controlled by the crew and will be the backup voice communications subsystem. The SARSAT beacon is controlled by the GPC. A voice intercom subsystem will be provided to the Space Station audio subsystem. Data communication with the Space Station will be provided through a direct interconnect between the CERV MDM's and the Space Station data busses.

The Global Positioning System (GPS) receiver, which will have redundant antenna selected by either the GPC or manually by the crew, will provide direct inputs to the GPC for the state vector. The GPS will be the primary source of state vector with backup being provided by the Space Station or the ground through the S-band subsystem.

The single-string S-band subsystem will have three antennas selected by either the GPC or manually and will be the primary voice, telemetry, and command uplink subsystem. The voice subsystem will have the UHF subsystem for backup but the telemetry and command subsystem will have no backup. A failure of this subsystem would not endanger the CERV mission.

Power

The power subsystem as conceived for the reference configuration is a lithium-bromine complex (LI-BCX) battery pack. The size and weight of the CERV batteries have been determined based on the requirements of the minimum weight and volume, minimum on orbit maintenance, minimum turn-on time at time of use, and redundancy. Although a 4-year shelf life is desired, shelf life data for this subsystem is only available for two years. It is anticipated that shelf life data to support the 4+ years shelf life will be available by the mid-1990's. Storage temperature of zero degrees Fahrenheit would enhance storage life.

Power safety plugs complete the circuit between power busses and controllers when installed after the CERV is berthed to the Space Station. This ensures no battery drain prior to connection to the main power controllers.

The Electrical Power Distribution Subsystem (EPDS) is conceived to be designed for single fault tolerance and to be capable of providing the energy needed for the CERV mission. Two separate power controllers will distribute power even if a battery subsystem or controller fails. The individual power controllers can be switched to the other battery bus for additional redundancy.

The CERV GPC will provide automatic control and fault detection for the EPDS. Essential power from each battery bus will provide power to the GPC's and MDM's. Power to these subsystems can also be provided through the main buses. Figure 4 depicts the Electrical Power System.

Another battery concept of interest is the Lithium Reserve Battery. In this application the battery electrolyte is stored in a separate reservoir until the CERV is required to be activated for a mission. Upon activation the electrolyte is injected into the battery cells. This approach provides long-term on orbit storage without voltage degradation and minimizes battery thermal requirements. This concept, however, would require Space Station power for periodic test and checkout of the CERV.

Summary

The Crew Emergency Return Vehicle (CERV) is being defined to provide Assured Crew Return Capability (ACRC) for Space Station Freedom. The CERV, in providing the standby "lifeboat" capability, would remain in a dormant mode over long periods of time as would a lifeboat on a ship at sea. The vehicle must be simple, reliable, and constantly available to assure the crew's safety. The CERV must also provide this capability in a cost-effective and affordable manner.

The CERV Project philosophy of a simple vehicle is to maximize its useability by a physically deconditioned crew. The vehicle reliability goes unquestioned since, when needed, it is the vehicle of last resort. Therefore, its systems and subsystems must be simple, proven, state-of-the-art technology with sufficient redundancy to make it available for use as required for the life of the program.

The CERV Project Phase A'/B Request For Proposals (RFP) is currently scheduled for release on October 2, 1989. The Phase A'/B effort will affirm the existing project requirements or amend and modify them based on a thorough evaluation of the contractor(s) recommendations. The system definition phase, Phase B, will serve to define CERV systems and subsystems. The current CERV Project schedule has Phase B scheduled to begin October 1990. Since a firm CERV avionics design is not in place at this time, the above treatment of the CERV avionics complement for the reference configuration is not intended to express a preference with regard to a system or subsystem.

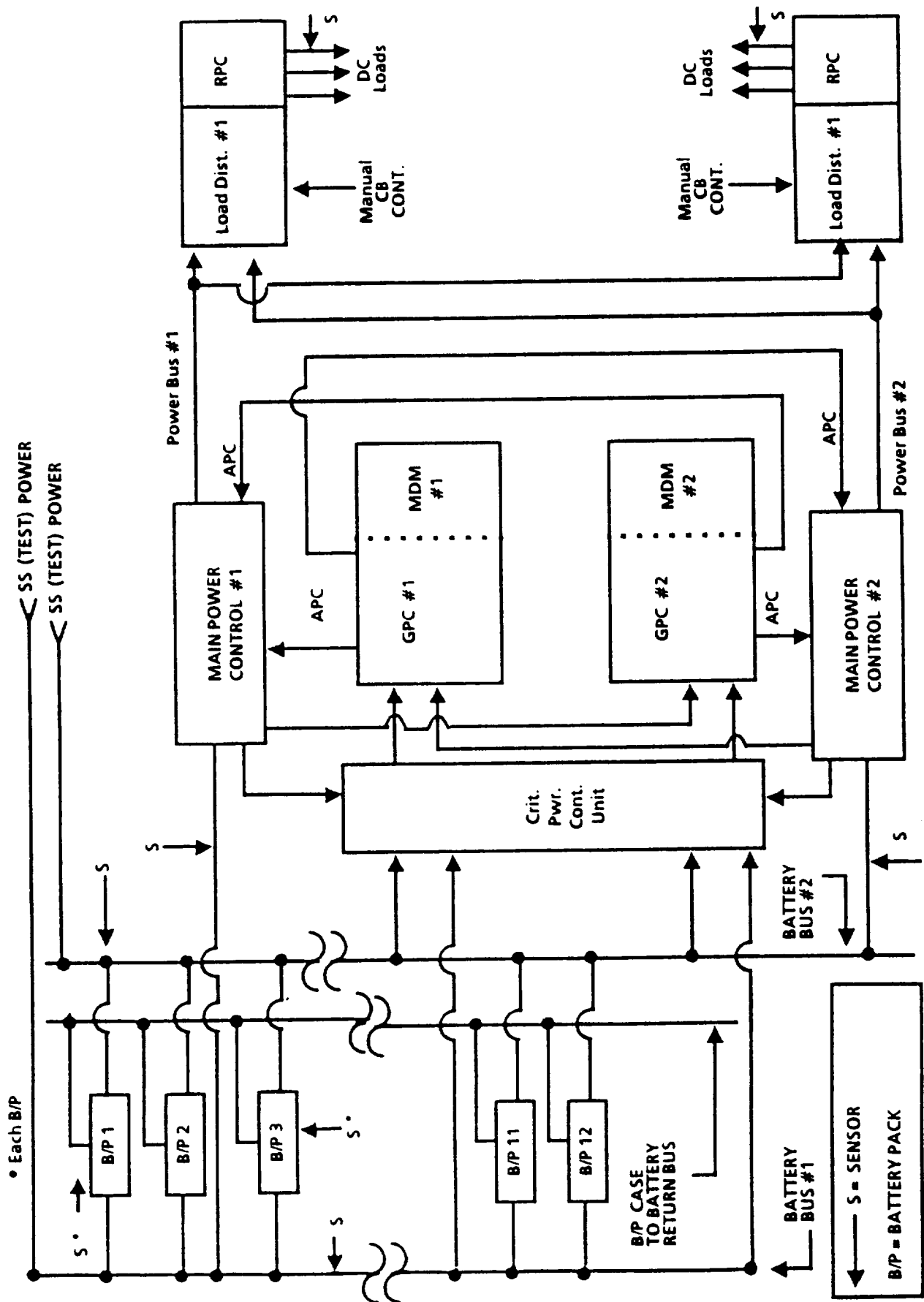


FIGURE 4. ELECTRICAL POWER SYSTEM

